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Improved Preventive Maintenance: Sealing Cracks in Flexible Pavements in Cold Regions

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Improved Preventive Maintenance: Sealing Cracks in Flexible Pavements in Cold Regions

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Abstract:	Cracking of asphalt pavements in cold regions has always presented a problem because it can directly affect pavement rideability and material behaviour, and therefore service life. Cracking, if left untreated, will develop into more drastic distresses such as spalling, pot-holes, deformation, and even structural failure. These distresses are irreversable and are a major factor in pavement surface roughness. A prime example is the transverse crack which, when left untreated, develops permanent and seasonal deformation in the form of lipping or cupping. Lipping is an upheaval and cupping is a depression of the pavement profile at the transverse crack. The Ontario Ministry of Transportation has an on-going preventive maintenance measure, a crack rout-and-seal program, to minimise the effects of cracking. The ministry also seeks to improve rout-and-seal methodology and discover better performing sealant materials. This presentation gives some up-to-date results from these investigations.
Key words:	asphalt pavement cracks, consequences of deferred maintenance, equipment, improved rout-and-seal methodology, preventive maintenance, sealant
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1. Introduction

When very severe pavement distress results in a very rough surface or deteriorated surface condition which is hazardous to the travelling public, urgent corrective maintenance is undertaken to remedy the situation. But such rough and/or hazardous conditions need not exist if timely preventive maintenance is undertaken.

A case in point, sealing of the initial transverse crack (Figure 1) at the appropriate time would have stopped or delayed the distress from developing into this impossible situation.

Cracking of asphalt pavement in cold region has always been a problem because it can directly affect pavement rideability and therefore service life. A prime example is the transverse cracks, which, if left untreated, will develop permanent deformation in the form of lipping or cupping at the crack. Lipping is the upheaval of the pavement profile at the crack (Figure 2), and cupping is a depression of the pavement profile at the crack (Figure 3). These deformations are irreversible and they are a major factor in pavement surface roughness.

Maintenance of cracks until about 10 years ago, was generally carried out in our Ministry by sealing with 'Spray Patch' treatment, that is, spraying of emulsion over the crack and blotting with a sand aggregate or stone-chips. However, the success rate of this treatment was much less than acceptable, not only because of the treatment itself but because of its inappropriateness for the distress (Figure 4). In many instances, the presumed cure is worse than the disease because the treatment can, and generally will, create additional roughness on an otherwise acceptable pavement riding surface, thus lowering its serviceability (Figure 5).

During the early 1970's, the Ministry began to seal cracks with the method commonly known as rout-and-seal, using as standard the same rout configuration of 19 mm wide and deep designed for concrete pavement joints and the hot-pour rubberized asphalt sealant developed for the same purpose. However, requirements for sealing characteristics of concrete pavement and asphalt pavement are substantially different. Therefore, the results of the early rout-and-seal programs, were less than a complete success.

This led to the questioning of the value of crack sealing as a viable maintenance treatment -- Is it true, as some advocate, that it is merely a waste of money and time as cracking will always be with us; or is it truly beneficial and would it be pennywise and pound foolish to do nothing?

To answer this question, it is essential to know the consequences of deferring sealing of cracks, and to know the cost-effectiveness of the rout-and-seal maintenance treatment.

For the Ministry, it is imperative because the on-going rout-and-seal programme has grown from an annual cost of mere tens of thousands to millions dollars in the latest fiscal years.

The Ministry began to address this issue in 1980 through a series of studies to improve the rout-and-seal technology as well as cooperating with the manufacturing sector to produce better performing sealant materials.

This presentation provides some up to date results of these studies begun in 1980.

2. Consequences of Deferred Maintenance on Cracking

Deferred maintenance of cracking is generally accepted, mainly due to budgetary constraint. However, our pavement designers are beginning to be concerned because the majority of our asphalt pavement mileage with untreated transverse cracks is developing either lipping or cupping deformations, in many instances very severe. In the view of the pavement designers, this concern is well justified because these deformations are costly to redress under the rehabilitation programme and simply resurfacing with hot-mix asphalt only perpetuates the cycle of reflection cracking and subsequent cupping or lipping.

Investigation shows that the surface condition of cracking does not necessarily indicate the degree of deterioration.(1) The deterioration can take place at the bottom of the asphalt layers, as illustrated in Figure 6. For heavily trafficked highway, deterioration can become so severe that half or more of the original asphalt layers will disintegrate from the bottom upward, creating a pavement of two different structural thicknesses within a matter of one metre or 3 feet plus and minus (Figure 7).

Consequences of not sealing cracks, are therefore, 1) increased maintenance costs because deteriorated cracks are difficult (see Figure 1) and expensive to repair through corrective maintenance, 2) increased user costs (vehicle repair and operation), 3) increased rehabilitation cost, because deteriorated cracks will demand special treatment from the designer when pavement rehabilitation is scheduled, and 4) loss of serviceability and therefore service life (1).

3. Cost Effective Maintenance Of Asphalt Pavement Cracking

The Ministry employed two maintenance treatments for cracks which are sealing with emulsified asphalt, and rout-and-seal with hot-pour rubberized asphalt sealant materials. Of these two treatments, time has demonstrated that sealing with emulsified asphalt is not only ineffective but can create undesirable side-effects.(2) However, rout-and-seal treatment has shown some success in effective maintenance of cracking, although the question of how cost-effective this particular maintenance alternative is, is still not answered.

Cost-effectiveness of a maintenance treatment depends on:

(1) how it will change the existing condition, that is, how effectively it corrects the existing distress;

(2) how well it can delay the distress's deterioration process, and thereby extend the pavement service life; and

(3) Is there a paticular condition or time during the progression of the cracking distress when appropriate maintenance can be most effective?

The information needed to establish cost-effectiveness of the rout-and-seal maintenance treatment must quantify:

(1) the effectiveness of treatment, that is,
   (a) performance of sealant materials over time
   (b) performance of various rout width and depth sizes over time to establish the most efficient rout configuration

(2) the extension of pavement service lite, that is
   (a) retarding of additional crack development
   (b) delaying the deterioration process of the existing distress

(3) the influence of time, that is, at which point of the pavement's life cycle the treatment is most cost-effectively applied.

3.1 In Search Of Effective Treatment

3.1.1 Effective Sealant Materials

Prior to 1980, the Ministry maintained a Designated Source List of approved sealant materials which must conform to ASTM D-1190 plus the Ministry Specification 1212 requirements.

Opinions were expressed in the industry and within the Ministry that these materials were evaluated and approved for use on Portland cement concrete pavement, and not necessarily effective when used to seal asphalt pavement cracks.

In 1980, manufacturers of sealant materials were invited to participate in a field evaluation of their materials under identical and controlled conditions to identify which crack sealant is best suited for sealing asphalt pavement cracks. (3)(4)(5).

In 1983, the study identified eight sealant materials as approved products based on mid-winter performance records. Four "premium" materials were approved for use in asphalt pavements throughout Ontario, namely:

1. Shell Cariphalte ELT
2. Bemac Supergook
3. Meadows Hi-Spec
4. Hydrotech Sealz 6165

These materials are of low stiffness modulus and formulated to meet ASTM D-3405.(6)

Four other materials considered as marginal were approved for use in asphalt pavement located in the Southern part of the province only, namely:

1. Bakelite 590-13
2. Hydrotech Sealz 6160
3. Meadows 164R
4. Paraseal 2065

These materials are of high stiffness modulus and formulated to meet ASTM D-1190.(6)

The Designated Source list is constantly reviewed and changes made (Table 1 and 2). Deletion from the list means either the product is no longer marketed by the manufacturer or because of unsatisfactory performance revealed by continuing monitoring.

3.1.2 An Effective Rout Configuration

Prior to 1980, the Ministry used the 19 x 19 mm rout configuration as standard for Portland cement concrete pavement joint sealing. This same standard was also used for asphalt concrete pavement joints and cracks. (7)

Opinions were expressed within the Ministry that this rout configuration was not the most effective for asphalt pavement because the extensibility and adhesion requirements at low temperature are not the same for Portland cement concrete and asphalt concrete pavement.

In 1981 and 1983, studies were initiated to identify the most efficient rout configurations from various combinations of width and depth.(2)(6)(7)

The result was that the new configuration of 40 mm width by 10 mm depth (figure 8) was put into the Ministry Maintenance Operation Instruction Guide as an optional choice besides the standard 19 x 19 mm configuration for asphalt concrete pavement rout-and-seal guidelines.(8)

The logic for this configuration is that:

1. The shape factor is at a ratio of 4 to 1 rather than the standard configuration of 1 to 1. Therefore, under low temperature the extensibility required of the sealant materials induced much less strain on the sealant and minimized the cohesion failure in the material.

2. The shape factor provides a greater bonding area horizontally instead of the vertical bond faces for the standard square configuration. Therefore, extension force being less will in turn induce smaller adhesion stress on the sealant material thus minimizing the chance of bond failure.

Added benefits of the 40 x 10 mm configuration are that:

1. The wider rout width can accomodate sharp directional changes in the crack which cannot be duplicated by the routing machine, enabling the operator to more effectively cover the course of the crack.

2. Less stress on the routing machine and router bits which means higher productivity at less cost.

To date, although this configuration is optional, the majority of the in-house and contractual work were done using this 40 x 10 mm rout.

3.1.3 Efficient Work Procedure

Prior to 1980, rout-and-seal work procedure was the same standard as rout-and-seal Portland cement concrete pavement joints. That is, routed with a vertical router, cleaned with compressed air and flush-filled with hand-pouring cone or garden water-can. The process was slow due to the low productivity of the vertical router. Considerable adhesion failure was also experienced from the flush-filled procedure. This was in part due to the shrinkage of the sealant materials upon cooling and resulted in actual underfilled.(7)

Since 1980, a number of studies were undertaken to establish the most efficient rout-and-seal procedure with the best possible long-term performance of sealing the cracks.(1)(2)(6)(7)(9) The manufacturing sector also brought on stream a number of improved equipment designed for rout-and-seal operation.(6)(7)(9) The result is that processes were added or discarded based on their suitability and unsuitability.

For example, the Ministry will not advocate Band-Aid Sealing because snow-plowing in the winter removes the sealant as well as the snow and ice. Similarly, overfilling to 80 mm and strike off with a squeeze was also discarded because of additional labour, waste of sealant materials and snow-plow shearing of excess materials.(2)(6)(7) The Ministry recommends that whether 19 x 19 mm or the optional 40 x 10 mm is used, sealant materials should be overfilled just sufficiently to cover both edges of the routed crack, leaving the sealing materials standing slightly proud of the pavement surface (Figure 9). This additional material will provide sufficient coverage to compensate for shrinkage during the cooling process.(6)(7)

For equipment, the Ministry recommends the use of the Crafco and Marathon routers (both with cutter wheels) as the most efficient and productive of currently available routers. Hot-compressed air lance rather than compressed air blowers because it will efficiently remove dust and moisture to ensure better bond between the pavement and the sealant materials.(6)(7)(9)

The most efficient and productive operation arrangement was put together by the Ottawa District Maintenance staff of the Ministry, and serves a model for all in-house operation (Figure 10).

The train of manpower and equipment is set-up as follows:

1. Two Crafco or Marathon Routers with Operator operate ahead of the Equipment train.

2. Hot-Compressed-Air Lance, connected to propane tanks and compressed-air supply in a small truck, operating approximately 5 metres (15 feet) ahead of the truck for cleaning and drying routed crack of dust, debris, and moisture.

3. Double-Jacketed Oil Kettle, for sealant materials heated by propane burners, is towed behind the truck. Sealant is dispersed into routed crack by pump wand which maintains sealant at constant pouring temperature. The wand can reach up to 5 metre (15 feet) behind the tow-vehicle. That is, the maximum distance between the cleaning and sealing phases is only about 20 to 25 metres (60-80 feet) which results in no dust or debris reentering the routed crack prior to sealant being poured.

3.2 Cost Effectiveness Of Rout-and-Seal Treatment As A Preventative Maintenance Measure

The cost-effectiveness of a treatment can be measured by how long it can delay the distress's deterioration process and its ability to retard development of other distresses which are related to or are a consequence of the original distress.

In 1981, a small scale study was initiated by the Ottawa District Maintenance office to look into the consequence of sealing pavement cracks with rout-and-seal vs. deferring maintenance. (1)(7)

A section of Highway 17 near Ottawa was selected as it was originally constructed in 1965 with 115 mm (4 1/2 inches) of Hot-Mix Asphalt, and was rehabilitated in 1979 with 65 mm (2 1/2 inches) of Hot-Mix Asphalt because of extensive cracking. In 1981, 2 years after resurfacing, extensive transverse cracks reappeared and the pavement was routed-and-sealed as a preventive maintenance measure. Part of this pavement was used for the experimental study.

In 1985, an investigation was made on the deferred maintenance control section, i.e. no rout-and-seal, and the adjacent rout-and-seal study section.

Following is a summary of the findings and observations(1):

1. When transverse crack maintenance was deferred in the control section:
   (a) cupping deformation occurred and progressed to the "Moderate" category after six service years from rehabilitation (Figure 11).

(b) deterioration of the pavement material at the transverse crack continues upward from the original pavement and into the binder course of the resurfacing layers after six years of service (Figure 12).

(c) transverse cracks began to develop multiple cracks and spalling after six service years (Figure 13).

2. When transverse cracks were routed-and-sealed:

(a) cupping deformation will develop after six service years but only in the "Slight" category (Figure 14);

(b) deterioration of the pavement at the transverse crack upward from the original pavement was halted or retarded even after six service (Figure 15).

(c) transverse crack surface condition remains static with no spalling or secondary crack development (see Figure 14).

Although the project is still active and monitoring continues, interim conclusions are as follows:

1. Rout-and-seal treatment of transverse cracks effectively retards internal and external deterioration.

2. Rout-and-seal treatment of transverse cracks effectively slows down the progress of cupping deformation.

3. Comparison of the treated sections versus the Control Section indicates that rout-and-seal treatment of transverse cracks can extend serviceability of the pavement by at least four years.

3.3 Timing For Cost-Effective Application Of Rout-and-Seal Treatment

In 1986, the Ministry's Maintenance Branch initiated a more comprehensive study program to further investigate "Rout-and-Seal Treatment of Cracks as a Cost Effective Preventive Maintenance Procedure."(1) The scope of the study is province-wide to ensure complete coverage of the different climatic and environmental conditions that exist in Ontario.

One of the objectives is to establish the influence of timing of treatment or, simply put, at which point of the pavement's life cycle the treatment is most cost-effectively applied. To answer this question, pavement test sites were selected from age groups of less than 3 years, 4 to 6 years, and 7 to 9 years of service life since last constructed or rehabilitated. In this study, three rout configurations and three types of sealants are being used at 35 sites. The same crew and equipment was used at all sites.

4. Planning for Rout-and-Seal

It is recommended that rout-and-seal treatment of asphalt pavement crackings should be carried out within the first 5 years of pavement service life. However, the Ministry has also recently developed an expert system for recommending rout-and-seal of asphalt concrete pavement in cold areas code name ROSE.(10) ROSE encodes expertise derived from recent research and development studies and from experience gathered within the Ministry. Utilizing distress data collected at 2 year intervals, the program provides estimates of quantities of crack sealing work for pavements in a District or Region, for different desirable levels of rout-and-seal.

5. Summary

The rout-and-seal treatment is designed to seal asphalt concrete pavement cracks to prevent water from entering and damaging the pavement structure. It is doubly important for pavements in cold areas because of the combination of low temperature induced crack opening and the winter maintenance practice of snow and ice removal with salt.

Routing is used to open up the crack to accommodate enough sealant to provide an effective seal even after the pavement crack opens (avg. 10 mm.) from contraction at low temperature during the winter months. Sealing is water proofing the crack by bonding to the pavement surface and extending without fracture over the opened crack during the critical winter period.

However, it was realized that even the best sealant materials would not perform in the field if they were not properly installed in a clean, dry condition and using the correct rout configuration. Therefore, the Ministry has expended considerable effort to bring together the total package, that is:

1. The best performing sealant materials designed for the job.

2. The proper work procedure and equipment to ensure a well laid seal.

3. The proper timing for execution of this treatment.

The Ministry considers these effort worthwhile, because some studies have indicated that rout-and-seal, well executed in a timely manner can prolong pavement life by up to 5 years for asphalt concrete pavement.(7)

This can be economically significant since the cost to rout-and-seal a 2-lane highway is about $1,000 per kilometer and typical resurfacing cost is about $40,000 per kilometer. An added benefit is that when rehabilitation is scheduled, the pavement designer will not have a badly deteriorated pavement to deal with if timely maintenance was performed.

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TABLE 1. M.T.C. DESIGNATED SOURCES LIST FOR ENGINEERING MATERIALS

DS: 143.4

Designated Sources for: JOINT SEALING COMPOUNDS FOR USE IN ASPHALTIC CONCRETE PAVEMENT - HOT-POURED RUBBERIZED ASPHALT

Specification(s): (i) EMO BITUMINOUS SECTION (ii) OPSS-1212

Standards: OPSD 508.01, 508.02, 508.03

Manufacturer	Product	Supplier
(i) Products Suitable for Use in All Districts		
Bakelite Thermosets Ltd. 284 Watline Ave. Mississauga, Ontario L4Z 1P4 (416) 890-4800	590-13A Pouring Temp. 175-185°c	Manufacturer
Hydrotech Membrane Corp. 100 Amber Street, Unit #12 Markham, Ontario L3R 3A2 (416) 475-3880	Hot Poured Sealz Sealz 6165 Pouring Temp. 190-215°C	Manufacturer
W.R. Meadows of Canada Ltd. 130 Toryork Drive Weston, Ontario M9L 1X6 (416) 741-2220	Hi-Spec. Hot Poured Rubberized Asphalt Pouring Temp. 195-205°C	Manufacturer
Tremco (Canada) Ltd. 220 Wicksteed Ave. Toronto, Ontario M4H 1G7 (416) 421-3300	THC-200 Pouring Temp. 190 - 205°C	Manufacturer

NOTE: For all of the above products method of application is either by pressure or gravity feed

TABLE 2. M.T.C. DESIGNATED SOURCES LIST FOR ENGINEERING MATERIALS

DS: 143.4

Designated Sources for: JOINT SEALING COMPOUNDS FOR USE IN ASPHALTIC CONCRETE PAVEMENT - HOT-POURED RUBBERIZED ASPHALT

Specification(s): (i) EMO BITUMINOUS SECTION (ii) OPSS 1212

Standards: OPSD 508.01, 508.02, 508.03

Manufacturer	Product	Supplier
(ii) Products Suitable for Use in Districts 1-8 only		
Bakelite Thermosets Ltd. 284 Watline Ave. Mississauga, Ontario L4Z 1P4 (416) 890-4800	590-13M Pouring Temp. 175-185°c	Manufacturer
Hydrotech Membrane Corp. 100 Amber St., Unit 12 Markham, Ontario L3R 3A2 (416) 475-3880	Hot Poured Sealz 6160 Pouring Temp. 195-215°C	Manufacturer
W.R. Meadows of Canada Ltd. 130 Toryork Drive Weston, Ontario M9L 1X6 (416) 741-2220	No. 164 Hot Poured Rubberized Asphalt Pouring Temp. 195-215°C	Manufacturer
Tremco (Canada) Ltd. 220 Wicksteed Avenue Toronto, Ontario M4H 1G7 (416) 421-3300	THC 205 Pouring Temp. 190-205°C	Manufacturer
Globe Asphalt Products Ltd. 3300 Steeles Ave., West Suite 201 Concord, Ontario L4K 2Y4 (416) 738-4306	W.I. 317 Pouring Temp 195°C - 210°C	Manufacturer
Koch Materials Co. 43 Industrial St. Toronto, Ontario M4G 1Z2 (416) 421-2252	#9001 Pouring Temp. 200°C - 215°C	Manufacturer

NOTE: For all of the above products method of application is either by pressure or gravity feed

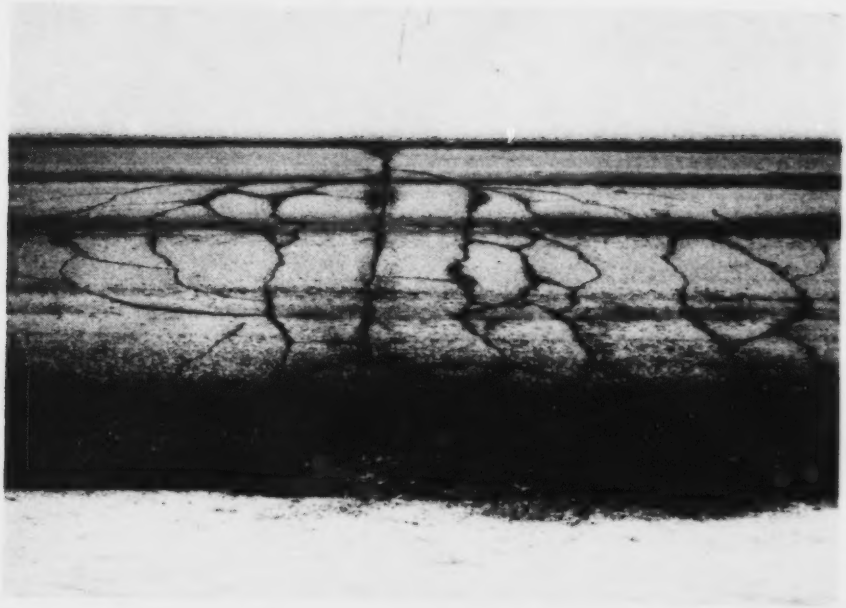

FIGURE 1. CONSEQUENCE OF DEFERRED MAINTENANCE OF TRANSVERSE CRACK

FIGURE 2. LIPPING OF TRANSVERSE CRACKS IN WINTER

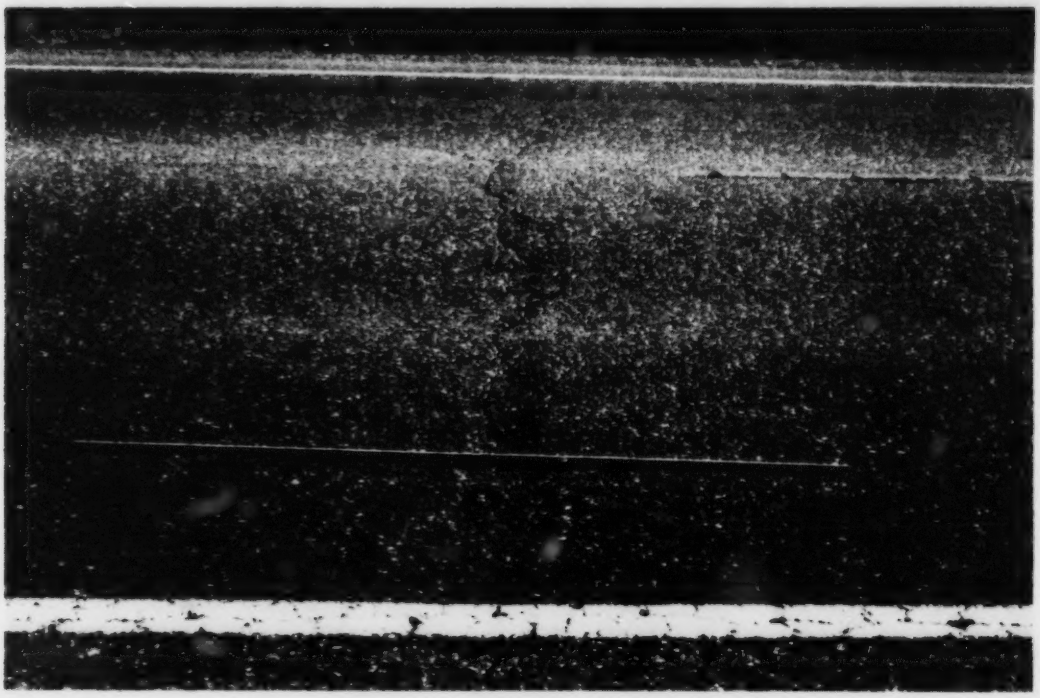

FIGURE 3. CUPPING OF TRANSVERSE CRACK IN SUMMER

FIGURE 4. SPRAY PATCH OF CRACK WITH EMULSION AND SAND AGGREGATE CRACK REMAINS UNSEALED

FIGURE 5. SPRAY PATCH OF CRACKS WITH EMULSION AND SAND AGGREGATE CREATED SMALL RIDGES AT CRACKS, DETRIMENTAL TO RIDEABILITY

FIGURE 6. HIGHWAY 15 INVESTIGATION SITE FOR UNSEALED TRANSVERSE CRACK DETERIORATION

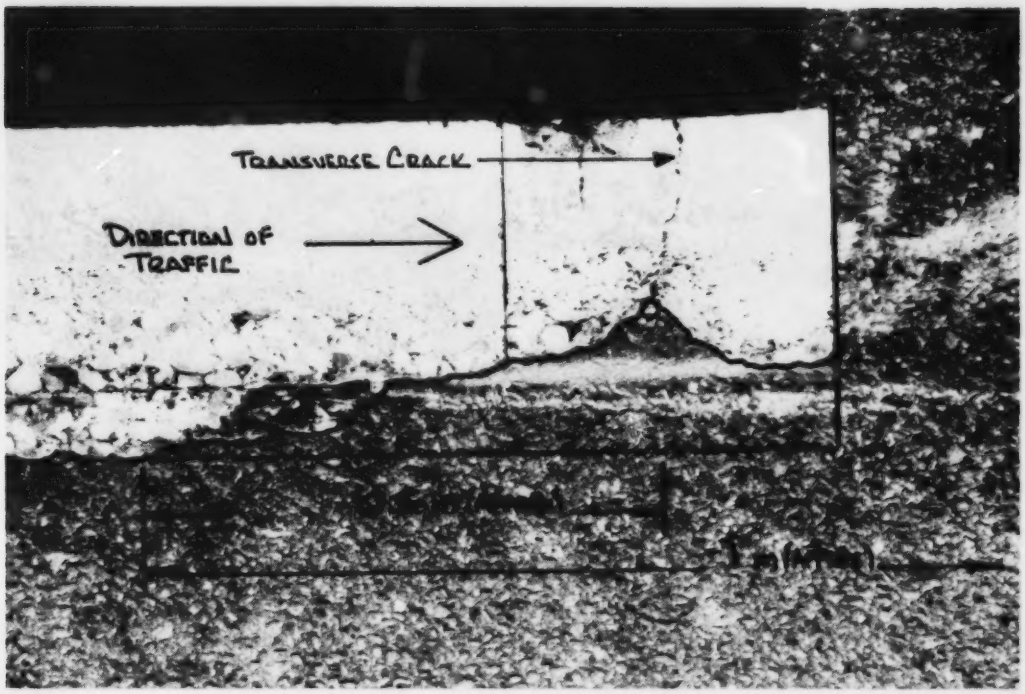

FIGURE 7. HIGHWAY 401 INVESTIGATION SITE FOR UNSEALED TRANSVERSE CRACK DETERIORATION

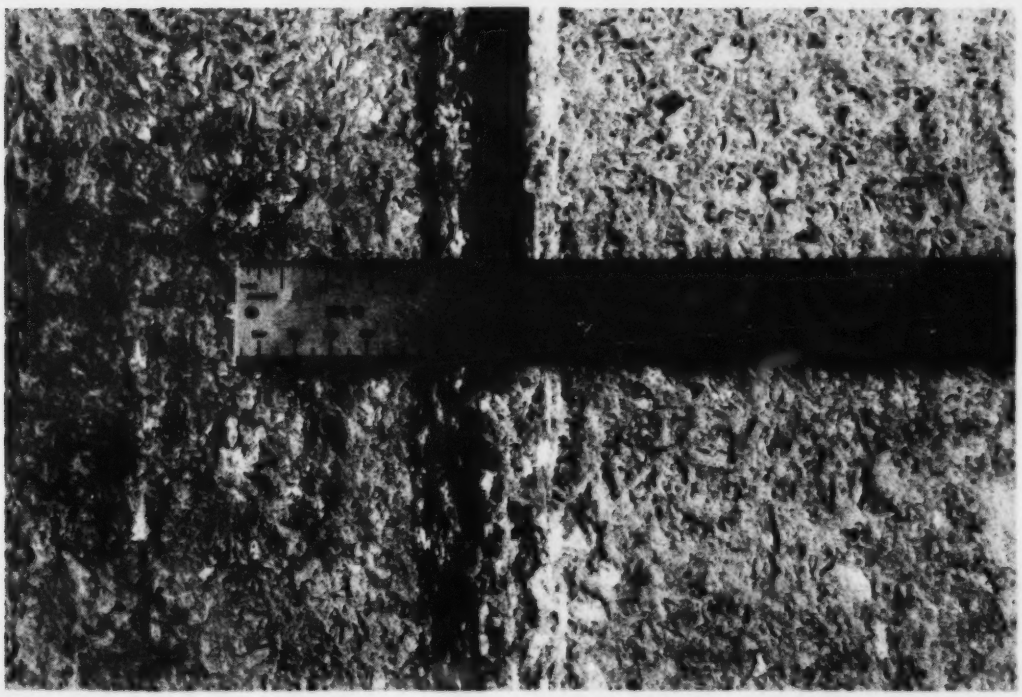

FIGURE 8. ROUT CONFIGURATION 40 mm X 10 mm

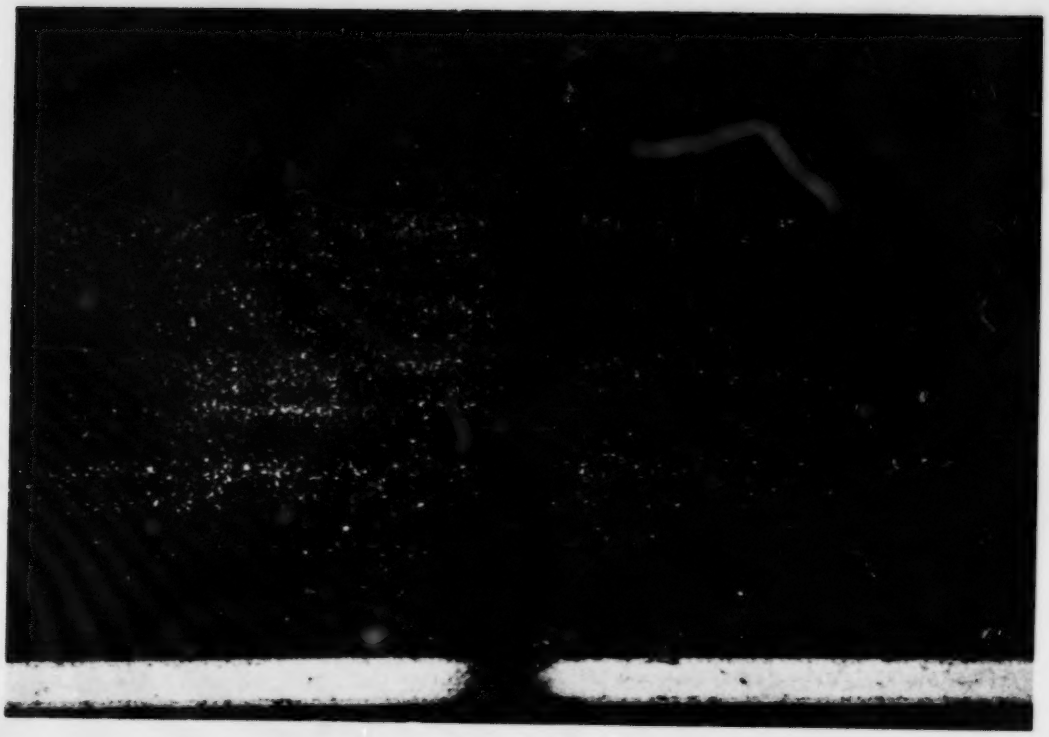

FIGURE 9. RECOMMENDED SEALANT MATERIALS OVERFILLED SUFFICIENT TO COVER EDGES OF ROUTED CRACK

FIGURE 10. STANDARD MINISTRY EQUIPMENT TRAIN FOR IN-HOUSE ROUT-AND SEAL OPERATION

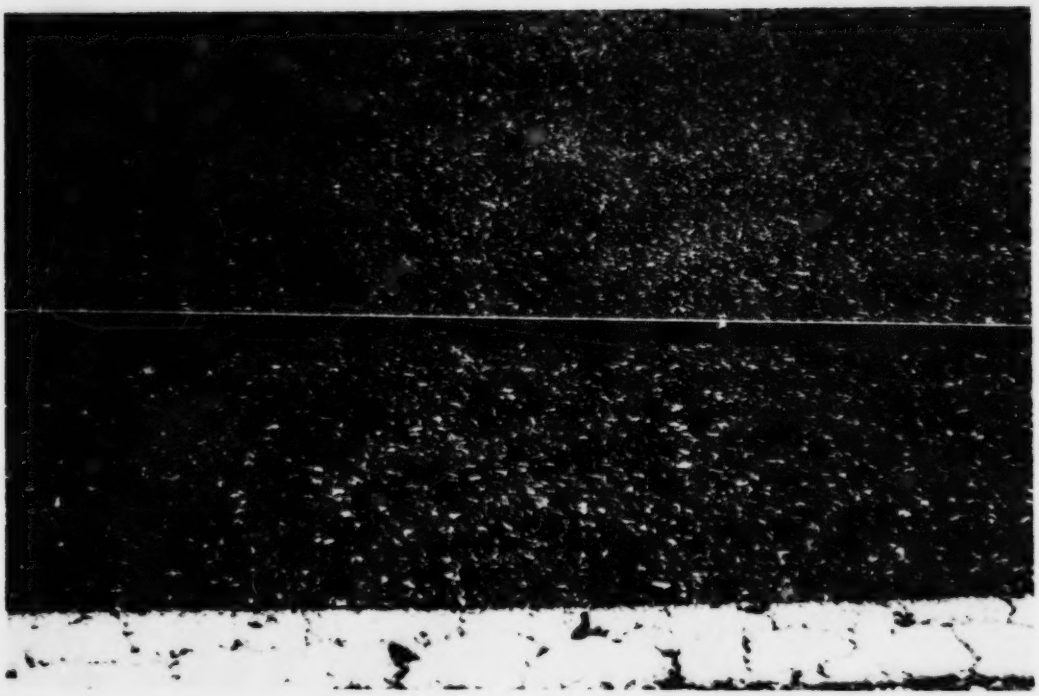

FIGURE 11. MODERATE CUPPING OF TRANSVERSE CRACK ON HIGHWAY 17. CONTROL SECTION

FIGURE 12. UNSEALED TRANSVERSE CRACK DETERIORATION CONTINUES UPWARD UNCHECKED ONHIGHWAY 17. CONTROL SECTION

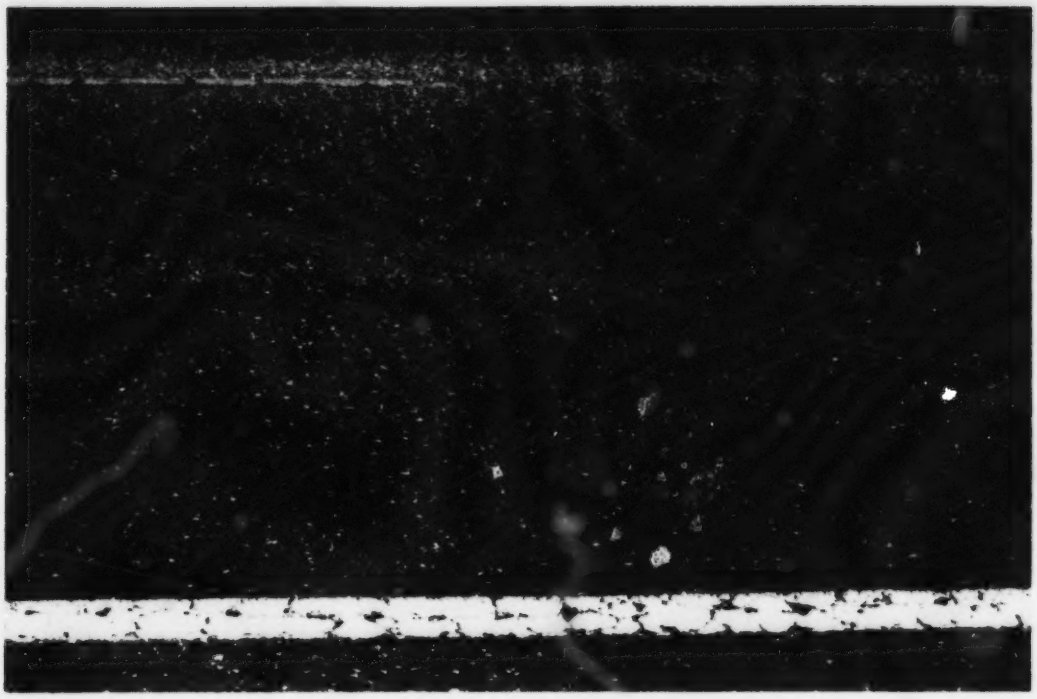

FIGURE 13. UNSEALED TRANSVERSE CRACK DEVELOPS MULTIPLE CRACKING AND SPALLING ON HIGHWAY 17. CONTROL SECTION

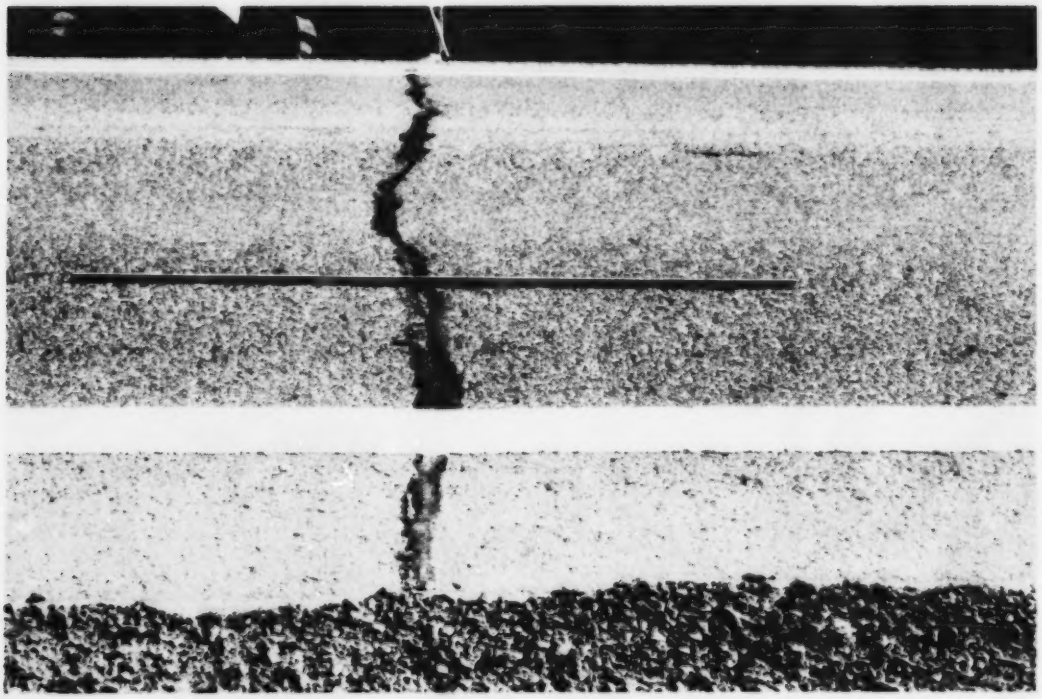

FIGURE 14. SLIGHT CUPPING OF TRANSVERSE CRACK ON HGIHWAY 17. SEALED TEST SECTION WITH HYDROTECH 6160

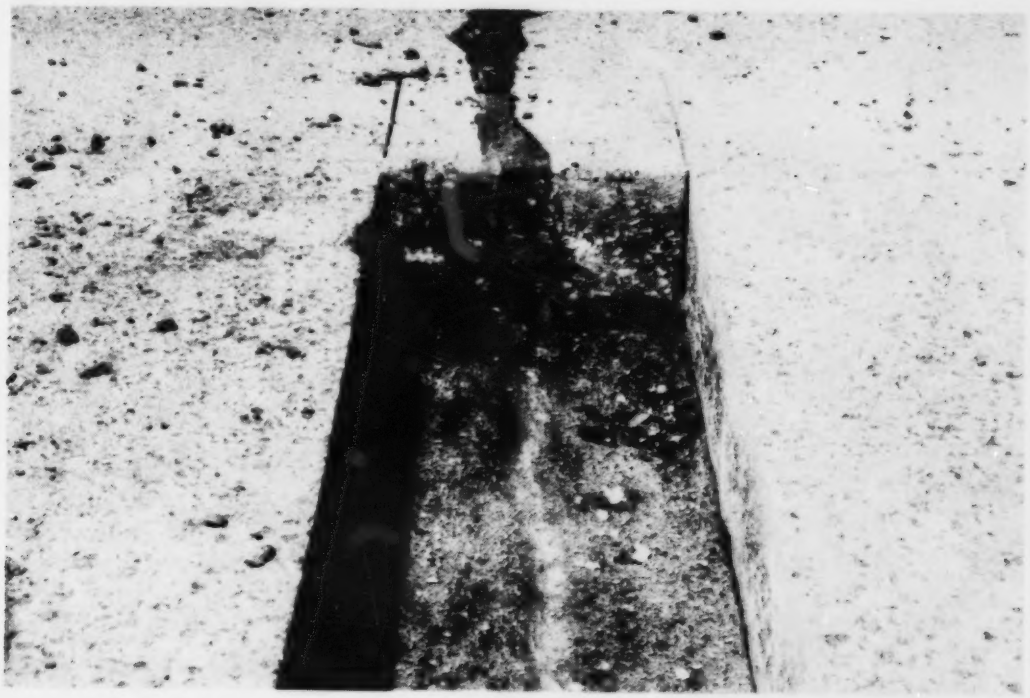

FIGURE 15. SEALED TRANSVERSE CRACK ORIGINAL DETERIORATION STOPPED OR RETARDED FROM PROGRESSING UPWARD ON HIGHWAY 17. SEALED TEST SECTION WITH HYDROTECH 6160